IMPLEMENTATION OF A PROGRAM TO ASSESS NEIGHBORHOOD LEVEL VARIATION IN AIR QUALITY IN NEW YORK CITY

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1. INTRODUCTION

Despite improvements over time, New York City's air quality does not meet clean air standards for fine particles ($PM_{2.5}$) or ground level ozone (O_3). In 2007, New York City's long term environmental sustainability plan, known as PlaNYC, was released including a number of city initiatives to improve local air quality. Because of growing evidence linking intra-urban air pollutant gradients to health impacts, PlaNYC also called for the New York City Department of Health to launch a study of neighborhood air quality.

2. BACKGROUND

The New York City Community Air Survey (NYCCAS) is designed to assess neighborhood level variation of levels of combustion-related pollutants. The goals of the survey are to inform local air quality management initiatives, to assess the contribution of air pollution exposure disparities to neighborhood health disparities, and to provide exposure estimates for future health studies.

At each of 150 sites, once per season, we collect two-week integrated samples of fine particles and constituents, elemental carbon (EC), nitrous oxides (NO_x), sulfur dioxide (SO_2), and ozone. One reference site in each of the five boroughs is sampled every session to capture overall temporal variability.

We produce Land Use Regression (LUR) models to estimate the relationship between pollutants and land use variables. These models are used to examine and compare fine-scale variability in multiple pollutants across seasons, to produce concentration estimates at unmonitored locations, to improve source identification, and to examine modification by site characteristics and meteorology.

3. METHODS

3.1 Spatial Allocation

Spatial assignment of sampling sites aimed to ensure coverage in:

- important source indicators for LUR modeling
- areas with high variability in air quality and vulnerable populations
- all community districts
- near transportation facilities and other source concentrations
- two (2) or more public open space sites per borough.

In GIS, we divided New York City into 7,756 cells (300m x 300m), created spatial covariates (e.g. traffic, population, building density, industrial land use, asthma hospitalizations, emission estimates), and evaluated distributions.

3.2 Systematic Sites

Traffic density and building density, proxies for important local sources, displayed highly skewed distributions and strong correlations with other neighborhood characteristics. Our systematic sampling method over-sampled the upper tails of these two variables, resulting in adequate

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representation of other neighborhood characteristics of interest.

We stratified lattice cells into the upper ('high') vs. lower three ('norm') quartiles of traffic and building density, creating four strata. 120 lattice cells were randomly selected without replacement with equal probability of assignment from each stratum, excluding the eight cells abutting each selected to reduce spatial clustering.

3.3 Purposeful Sites

After receiving input from local environmental groups and government stakeholders, 30 locations were assigned to fill spatial gaps and capture sources of interest. Purposeful sites were chosen to:

- Ensure one or more monitors per community district
- Minimize spatial gaps between monitors.
- Co-locate monitors in 'street canyon' locations
- Ensure two or more public open space sites per borough
- Capture key combustion sources of interest such as areas of traffic congestion, ferry/bus terminals, and power stations

Field teams selected lamp posts or utility posts for mounting sampling equipment in the nearest residential or commercial area so that monitoring would capture community exposure to potential sources.

3.4 Reference Sites

One site per borough (5) was selected away from traffic and building sources to serve as reference locations to be used in temporal correction. These are centrally located in parks or co-located with New York State regulatory roof-top monitors.

3.5 Selecting Monitoring Posts

Field teams were provided maps and orthophotos with points indicating the nearest curbside location to the randomly selected lattice cell centroid or purposeful location of interest. Teams visited sites and selected the nearest lamp post or utility post suitable for mounting the NYCCAS air monitor. Teams collected field data on each site including road type, traffic characterization, tree cover, land-use, and information on nearby sources.

3.6 Final Monitoring Locations

The final set of 150 monitoring locations and five reference sites are displayed with traffic density overlay (Fig. 1) and building density overlay (Fig. 2).

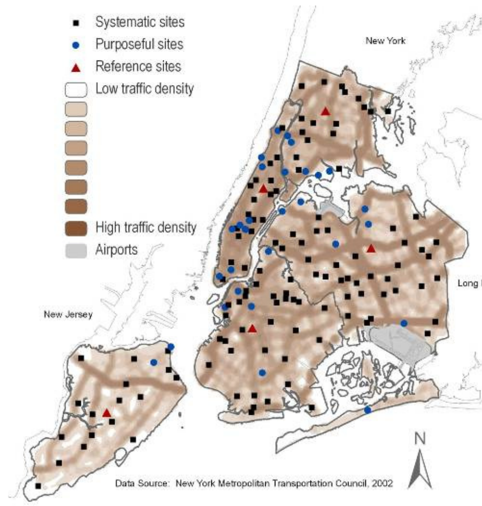


Fig. 1. NYCCAS monitoring locations with traffic density derived from 2002 New York Metropolitan Transportation Council (NYMTC) Data

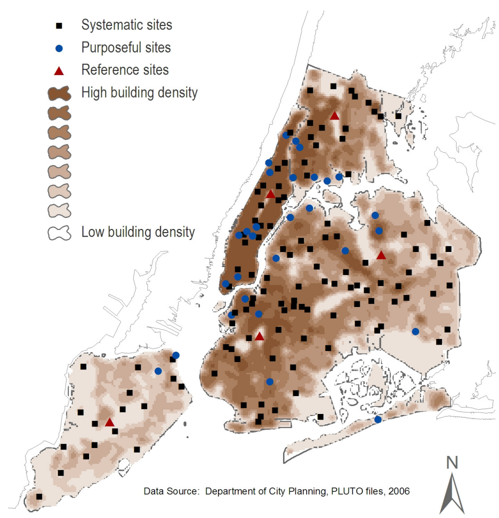


Fig. 2. NYCCAS monitoring locations with building area density from 2006 NYC Department of City Planning PLUTO data.

3.6 NYCCAS Sampling Unit

Target pollutants include: $PM_{2.5}$, NO_x, EC, SO_2, O_3, and $PM_{2.5}$ elemental constituents. The NYCCAS integrated sampler was designed as a field durable monitoring package that can be mounted on light posts to a pre-installed mounting plate to facilitate rapid deployment and retrieval in an urban setting (Fig. 3). $PM_{2.5}$ is collected with a Harvard impactor operated for 15 minutes each hour for a two week period (84 hour sample). A programmable control unit regulates the pump, restarting or stopping the pump if it detects unexpected deviation from the scheduled run time, and records pump performance. Pump start and stop times are pre-programmed to begin and end at midnight, ensuring all sites are sampled simultaneously. NO_x, SO_2, and O_3 are collected with passive Ogawa badges, mounted in a protective housing. A temperature/RH sensor and data logger records temperature and relative humidity for use in adjusting gaseous pollutant measurements and correcting sample volume for variation in flow rate with temperature.

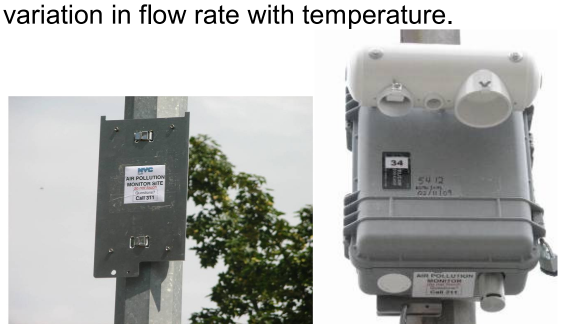


Fig. 3. NYCCAS pre-installed mounting plate and NYCCAS air sampling unit mounted on lamp-post.

3.7 Field Implementation

We collect integrated samples at each of the 150 sampling locations for two weeks each season. Reference sites are sampled during every two-week session. At three reference sites (10% of sites) we deploy blank samplers that consist of $PM_{2.5}$ filters in Harvard impactors under no air flow and Ogawa badges that remain sealed in shipping jars. We co-locate 15% of sites (both street-side and reference) by deploying units side by side on lamp or utility posts.

Three field teams deploy and retrieve 30 sites and the beginning and end of every two week period. During deployment and retrieval activities teams collect relevant site observations such as tree cover or construction activity.

3.8 Sample Analysis

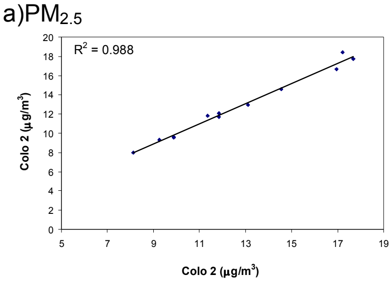
Gravimetric analysis is performed on $PM_{2.5}$ filters to determine particle mass. Filters are analyzed for EC using a reflectometer while elemental constituents are determined by X-Ray Flourescence (XRF). NO_x and NO_2 are determined by spectrophotometry and O_3 and SO_2 are determined by ion chromatography.

4. RESULTS

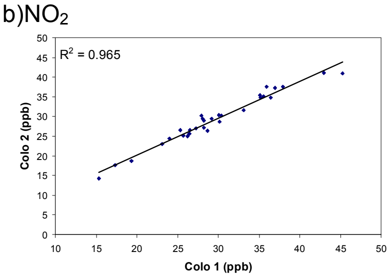
The monitoring for the first season (winter) was completed between December 16, 2008 and March 11, 2009 to produce 192 $PM_{2.5}$ and 210 NO_2-NO-NO_x-SO_2 two week monitoring events (including field, reference, and co-located samples). Despite minimum temperatures reaching less than -10 degrees Celsius in five of six sessions, 93% of particle samples meet criteria for sample volume and flow rate. More than 99% of gaseous samples were successfully retrieved, with no attrition to vandalism.

Preliminary first season data showed good reproducibility in co-located measurements of NO_x species, SO_2 and $PM_{2.5}$ (Fig. 4) and agreement with co-located New York State Department of Environmental Conservation (NYDEC) regulatory monitors (Fig. 5).

a)$PM_{2.5}$



b)NO_2



c)SO_2

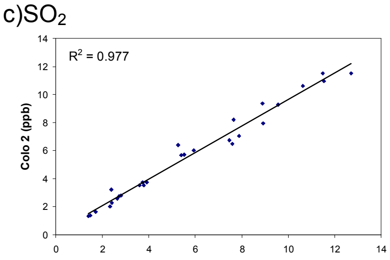
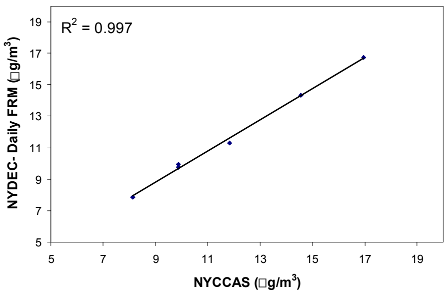
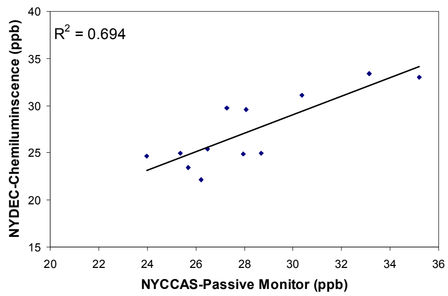


Fig. 4. Comparison of measures of $PM_{2.5}$ (a), NO_2 (b), and SO_2 (c) from side by side co-located NYCCAS monitors

a) $PM_{2.5}$



b) NO_2



b) SO_2

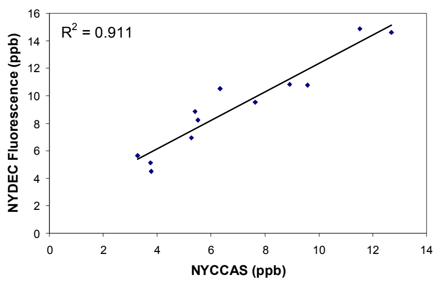
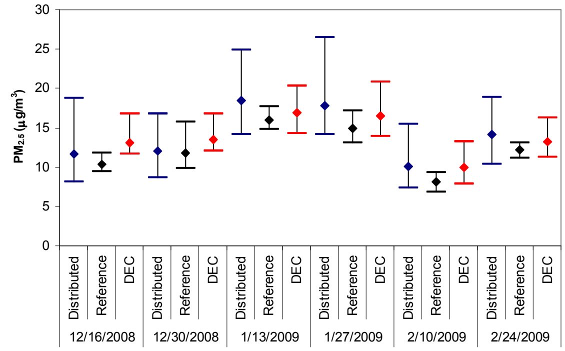


Fig 5. Comparison of NYCCAS measures co-located with NYDEC regulatory (a) $PM_{2.5}$ federal reference method gravimetric sampler (b) NO_2 chemiluminescence monitor and (c) SO_2 fluorescence monitor. All values are two-week average concentrations.

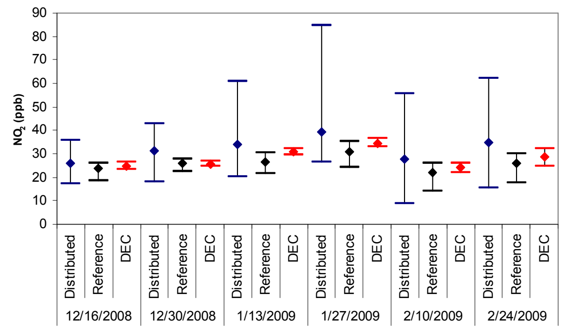
NYCCAS monitors showed temporal patterns similar to those observed at regulatory monitors (Fig 6). Spatial variability was observed across NYC NYCCAS sites (Fig. 6) ranging two-fold for $PM_{2.5}$ to 10-fold or more for NO_2 and SO_2.

While rooftop regulatory monitors provide highly temporally resolved measures of pollutant levels, Fig. 6 shows that NYCCAS monitors add increased spatial variability due to the larger number of sites and their spatial distribution throughout the city in areas of differing site characteristics.

a) $PM_{2.5}$



b) NO_2



b) SO_2

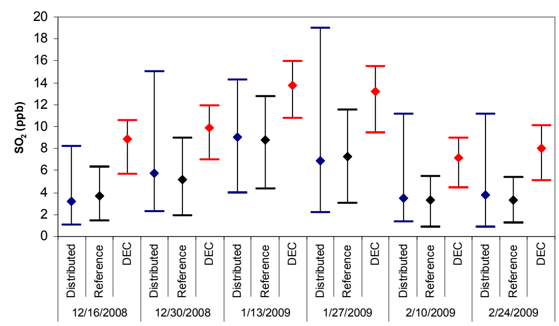


Fig. 6. Temporal tracking and variability of $PM_{2.5}$ (a), NO_2 (b), and SO_2 (c) at NYCCAS distributed (systematic and purposeful) sites, NYCCAS reference sites, and NYDEC regulatory monitors. Data displays mean, minimum, and maximum of two-week average concentrations.

Preliminary review of univariate relationships between pollutant concentrations and source proxies show correlations between monitored levels and hypothesized source proxies within 200 meter buffers of sampling locations (Table 1). We observe significant (p<0.05 displayed in bold) correlations between EC and NO_2 concentrations and all traffic, population, and building density metrics. $PM_{2.5}$ levels are significantly correlated with traffic and building density metrics while SO_2 levels are significantly correlated with population and building density metrics.

Table 1. Preliminary correlations between winter concentrations and selected source metrics within 200 meters.

	$PM_{2.5}$	EC	NO_2	SO_2
NYMTC traffic density	**.26**	**.26**	**.34**	.04
NYMTC truck traffic density	**.23**	**.31**	**.35**	.09
Census 2000 population	.15	**.25**	**.24**	**.35**
Buildings density	**.41**	**.45**	**.58**	**.35**
Residential space density	.14	**.21**	**.28**	**.32**
Commercial space density	**.41**	**.44**	**.57**	**.30**

Fig. 7 through Fig. 9 show spatial distributions of NYCCAS measurements of $PM_{2.5}$, NO_2, and SO_2 during the winter 2008-2009 with traffic and building density. The measurements have been temporally adjusted by displaying the difference between the sample measurement and the mean of the reference site measurements within that period.

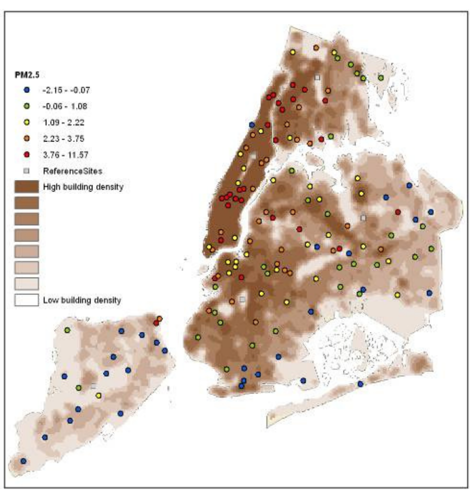


Fig. 7. Spatial distributions of temporally adjusted winter 2008-2009 $PM_{2.5}$ measurements with building density.

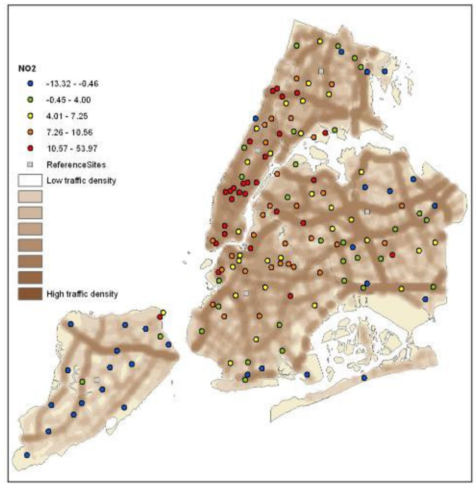


Fig. 8. Spatial distributions of temporally adjusted winter 2008-2009 NO_2 measurements with traffic density.

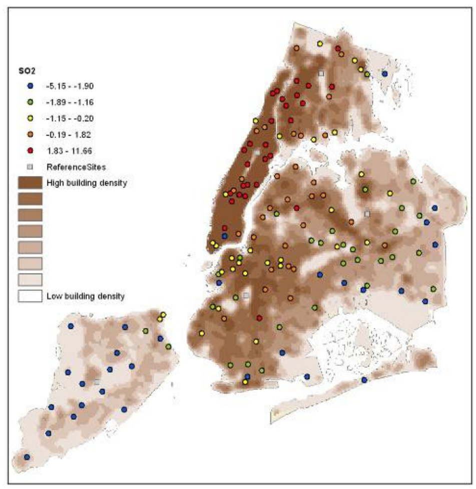


Fig. 9. Spatial distributions of temporally adjusted winter 2008-2009 SO_2 measurements with building density.

5. CONCLUSION

NYCCAS methods and instrumentation enable reliable and efficient measurements of multiple air pollutants across a variety of sites in a large city. Winter season measurements show significant spatial variability of pollutant levels within New York City, which are correlated with nearby traffic and building density.

Measurements are currently being used in developing land use regression models to assess intra-urban variability of air pollutants in relation to proxy measures of hypothesized sources. These models will allow us to produce concentration estimates at unmonitored locations, improve source identification, and help guide NYC air pollution policy.